U.S. DEPARTMENT OF COMMERCE
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PB-256 548

Chickahominy Lake, Charles City, and New Kent Counties, VA

Pacific Northwest Environmental Res. Lab.

Prepared For
National Environmental Research Center

June 1975

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
Report on Chickahominy Lake, Charles City and New Kent Counties, Virginia

5. REPORT DATE
Prepared June, 1975

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Anonymous (National Eutrophication Survey Staff)

8. PERFORMING ORGANIZATION REPORT NO.
Working Paper # 459

9. PERFORMING ORGANIZATION NAME AND ADDRESS
National Eutrophication Survey
U.S. Environmental Protection Agency
200 S. W. 35th St.
Corvallis, Oregon 97330

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
Office of Research and Development
U.S. Environmental Protection Agency
401 M Street, S. W.
Washington, DC 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final - 1973

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

PRICES SUBJECT TO CHANGE

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release unlimited		46 pp.
	20. SECURITY CLASS (This page)	22. PRICE
		$4.00

EPA Form 2220-1 (9-73)

243030

PB 256 548

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

An Associate Laboratory of the

NATIONAL ENVIRONMENTAL RESEARCH CENTER - CORVALLIS, OREGON

and

NATIONAL ENVIRONMENTAL RESEARCH CENTER - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

REPORT

ON

CHICKAHOMINY LAKE

CHARLES CITY AND NEW KENT COUNTIES

VIRGINIA

EPA REGION III

WORKING PAPER No. 459

WITH THE COOPERATION OF THE

VIRGINIA STATE WATER CONTROL BOARD

AND THE

VIRGINIA NATIONAL GUARD

JUNE, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Virginia State Water Control Board for professional involvement and to the Virginia National Guard for conducting the tributary sampling phase of the Survey.

Eugene T. Jensen, Executive Secretary of the State Water Control Board; Michael A. Bellanca, Director; Jean W. Gregory, Pollution Control Specialist; and Robert W. Pitchford, Pollution Control Technician; Bureau of Surveillance and Field Studies; provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

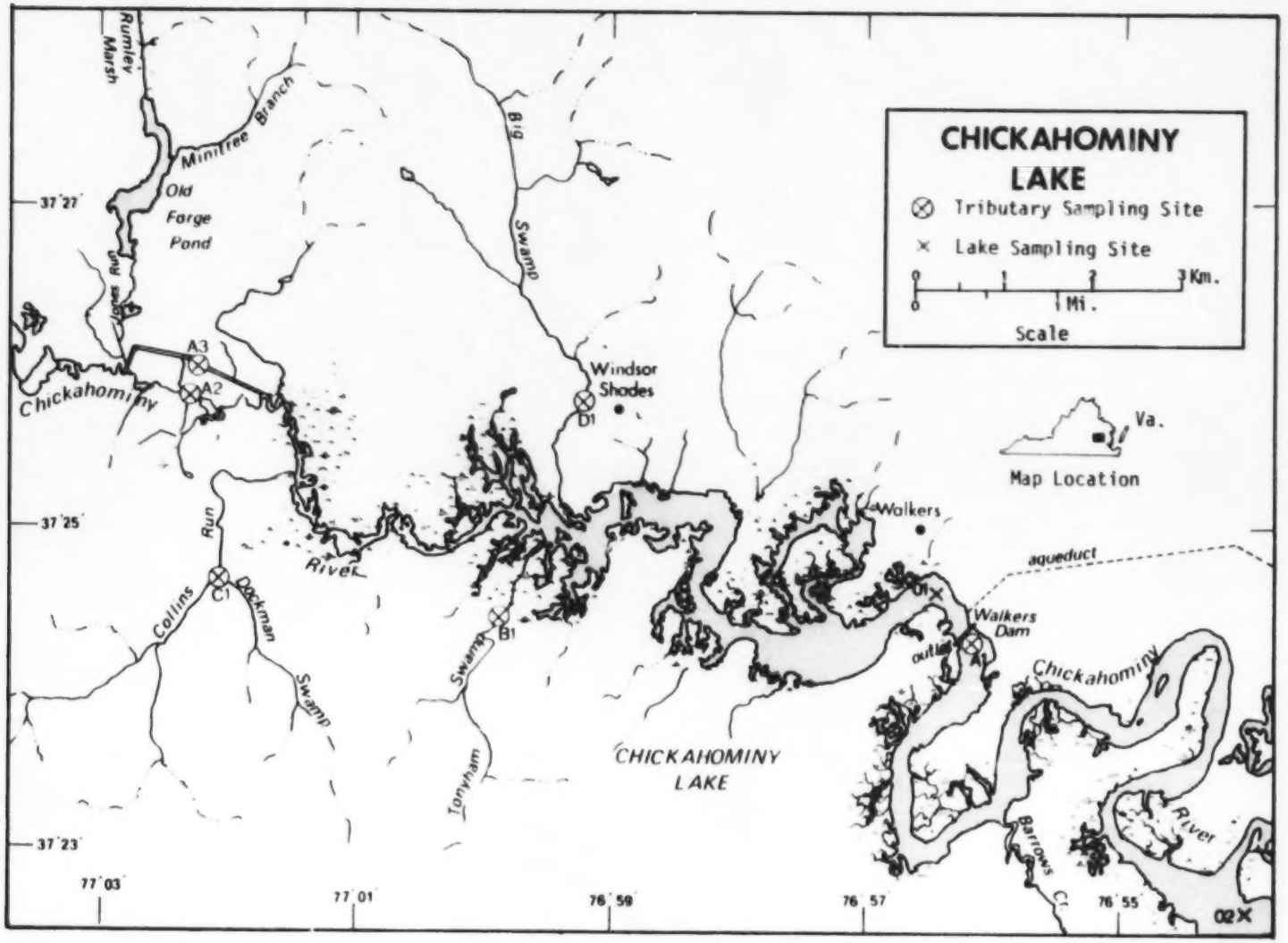
Major General William J. McCaddin, the Adjutant General of Virginia, and Project Officer Lt. Colonel James D. Manley, who directed the volunteer efforts of the Virginia National Guardsmen, also are gratefully acknowledged for their assistance to the Survey.

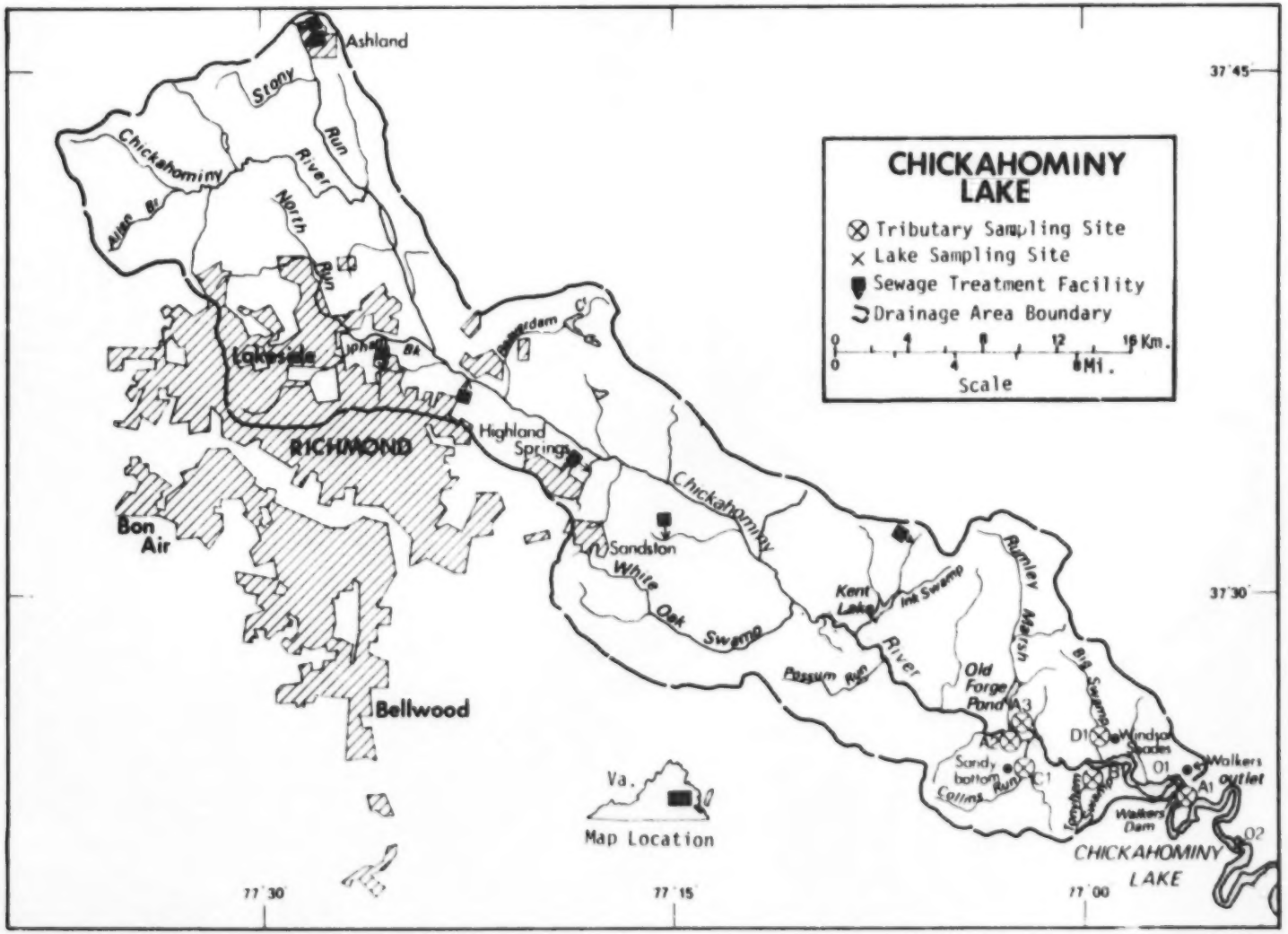
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF VIRGINIA

LAKE NAME	COUNTY
Bluestone	Giles, VA; Mercer, Monroe, Summers, WV
Chesdin	Amelia, Chesterfield, Dinwiddie
Chickahominy	Charles City, New Kent
Claytor	Pulaski
J. H. Kerr	Charlotte, Hallifax, Micklenburg, VA; Granville, Vance, Warren, NC
J. W. Flannagan	Dickenson
Occoquan	Fairfax, Prince William
Rivanna	Albemarle
Smith Mountain	Bedford, Franklin, Pittsylvania


CHICKAHOMINY LAKE
Tributary Sampling Site
Lake Sampling Site
0 1 2 3 Km.
0 1 Mi.
Scale
Va.
Map Location
Rumley Marsh
Minitree Branch
Old Forge Pond
Big Swamp
Windsor Shades
D1
A3
A2
Chickahominy
37°27'
37°25'
37°23'
77°03'
77°01'
76°59'
76°57'
76°55'
Run
Collins
Dorkman
Swamp
C1
River
Swamp
B1
Tonyham
CHICKAHOMINY LAKE
Walkers
aqueduct
Walkers Dam
outlet
A1
Chickahomini
River
Barrows Cr.
02


CHICKAHOMINY LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
0 4 8 12 16 Km.
0 4 8 Mi.
Scale
Ashland
Stony Run
Chickahominy
North Run
Lakeside
RICHMOND
Highland Springs
Bon Air
Bellwood
Sandston
White Oak Swamp
Chickahominy
Kent Lake
Old Forge Pond
Rumley Marsh
Walkers outlet
Walkers Dam
CHICKAHOMINY LAKE
Va.
Map Location
37°45'
37°30'
77°30'
77°15'
77°00'

CHICKAHOMINY LAKE

STORET NO. 5112

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Chickahominy Lake is eutrophic. It ranked fourth in overall trophic quality when the eight Virginia lakes sampled in 1973 were compared using a combination of six parameters*. Five of the lakes had less median total and dissolved phosphorus, none had less mean inorganic nitrogen, seven had less mean chlorophyll a, and three had greater mean Secchi disc transparency.

Survey limnologists noted large amounts of macrophytes in the shallow areas of the lake at all sampling times. The lake has been chemically treated to control extensive growths of egeria (= elodea), Egeria densa (Corning and Prosser, 1969; Anonymous, 1972a, 1972b, 1973a, 1973b).

B. Rate-Limiting Nutrient:

The algal assay results indicate that the lake was nitrogen limited at the time the sample was collected (04/09/73). The lake data indicate nitrogen limitation at station 1 in September as well but phosphorus limitation at station 2.

C. Nutrient Controllability:

1. Point sources--During the sampling year, listed point

* See Appendix A.

sources contributed over 35% of the total phosphorus load to the lake. The present phosphorus loading of 3.21 $g/m^2/yr$ is nearly three times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 12). Although Vollenweider's model may not be applicable to lakes with short hydraulic retention times, the existing trophic condition is evidence of excessive nutrient loads. Therefore, all phosphorus inputs should be minimized to the greatest practicable extent. Point-source phosphorus control should result in eventual phosphorus limitation in the lake and at least slow the present rate of eutrophication. To this end, the Virginia Water Control Board is requiring the County of Henrico and City of Richmond to eliminate all point-source nutrient discharges to the watershed (Ketelle and Uttormark, 1971); and the Highland Springs wastewater treatment plant included in this study was closed in April, 1974.

2. Non-point sources--During the sampling year, non-point sources contributed about 65% of the total phosphorus load to the lake. The Chickahominy River alone contributed almost 54% of the total phosphorus load. Tonyham Swamp, Collins Run, Big Swamp, and minor tributaries and immediate drainage collectively contributed about 10% of the total phosphorus load.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 6.07 kilometers^2.
2. Mean depth: 4.9 meters.
3. Maximum depth: Unknown.
4. Volume: 29.743 x 10^6 m^3.
5. Mean hydraulic retention time: 44 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Chickahominy River (A-2 & -3)	697.7	7.1
Tonyham Swamp	5.1	0.1
Collins Run	17.8	0.2
Big Swamp	14.7	0.2
Minor tributaries & immediate drainage -	33.0	0.5
Totals	768.3	8.1

2. Outlet -

Chickahominy River (including aqueduct)	774.4**	7.9

C. Precipitation***:

1. Year of sampling: 93.1 centimeters.
2. Mean annual: 108.7 centimeters.

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† Table of metric conversions--Appendix B.
†† Bellanca, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No 175.

III. LAKE WATER QUALITY SUMMARY

Chickahominy Lake was sampled twice during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. A planned mid-summer sampling was cancelled because of a July application of herbicides to control extensive growths of the aquatic weed egeria (Egeria densa). Near-surface and 1.8 meter samples for physical and chemical parameters were collected from the single station on the lake during the first visit (see map, page v), and near-surface samples were taken during the last visit. A second station, which was inadvertantly established eight miles downstream from the lake, was sampled in a similar manner. During each visit, a single depth-integrated (near bottom to surface) sample was composited from the two stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was collected for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 1.8 meters at station 1 and 1.5 meters at station 2.

The sampling results for both stations are presented in full in Appendix D, and are summarized in the following table for station 1.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR CHICKAMOMINY LAKE
STORET CODE 5112

PARAMETER	1ST SAMPLING (4/ 9/73) 2 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (9/26/73) 2 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING 0 SITES RANGE	MEAN	MEDIAN
TEMP (C)	14.1 - 14.5	14.3	14.3	23.5 - 24.0	23.8	24.0	******	**********	
DISS OXY (MG/L)	8.4 - 8.5	8.4	8.4	5.6 - 6.8	6.2	6.2	******	**********	
CNDCTVY (MCROMO)	70. - 75.	71.	70.	76. - 497.	356.	495.	******	**********	
PH (STAND UNITS)	6.6 - 6.8	6.7	6.8	6.5 - 6.6	6.5	6.5	******	**********	
TOT ALK (MG/L)	15. - 16.	15.	15.	21. - 30.	26.	26.	******	**********	
TOT P (MG/L)	0.062 - 0.092	0.071	0.066	0.054 - 0.069	0.061	0.061	******	**********	
ORTHO P (MG/L)	0.017 - 0.022	0.019	0.018	0.006 - 0.010	0.008	0.008	******	**********	
NO2+NO3 (MG/L)	0.050 - 0.070	0.057	0.055	0.030 - 0.030	0.030	0.030	******	**********	
AMMONIA (MG/L)	0.070 - 0.080	0.075	0.075	0.050 - 0.070	0.060	0.060	******	**********	
KJEL N (MG/L)	0.500 - 0.700	0.575	0.550	0.900 - 1.000	0.950	0.950	******	**********	
INORG N (MG/L)	0.120 - 0.150	0.132	0.130	0.080 - 0.100	0.090	0.090	******	**********	
TOTAL N (MG/L)	0.550 - 0.770	0.632	0.605	0.930 - 1.030	0.980	0.980	******	**********	
CHLRPYL A (UG/L)	4.9 - 11.0	7.9	7.9	18.4 - 20.1	19.2	19.2	******	**********	
SECCHI (METERS)	1.5 - 1.5	1.5	1.5	0.9 - 1.0	0.9	0.9	******	**********	

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/09/73	1. Melosira sp.	853
	2. Flagellates	820
	3. Pennate diatoms	292
	4. Dactylococcopsis sp.	258
	5. Nitzschia sp.	34
	Other genera	158
	Total	2,415
09/26/73	1. Melosira sp.	4,261
	2. Mougeotia sp.	355
	3. Stephanodiscus sp.	331
	4. Microcystis sp.	260
	5. Cyclotella sp.	237
	Other genera	1,895
	Total	7,339

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/09/73	1	4.9
	2	11.0
09/26/73	1	18.4
	2	20.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.020	0.068	2.1
0.050 P	0.070	0.068	2.6
0.050 P + 1.0 N	0.070	1.068	17.4
1.0 N	0.020	1.068	4.4

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Chickahominy Lake was high at the time the sample was collected (04/09/73). The lack of yield increase with the addition of phosphorus alone until nitrogen was also added, indicates that the lake was limited by nitrogen at that time. Note that the addition of nitrogen alone resulted in a yield much greater than that of the control.

The lake data indicate nitrogen limitation as well. The mean inorganic nitrogen/orthophosphorus ratios at station 1 were 6/1 and 8/1 in April and September, respectively. Note that the assay sample was a composite of lake station 1 and station 2 below the outlet (see maps, pages v and vi). The mean N/P ratio at station 2 was 4/1 indicating nitrogen limitation in April. However, in September the N/P ratio was 17/1, and phosphorus limitation would be expected.

Nitrogen limitation, as indicated by the algal assay or by in-lake nitrogen to phosphorus ratios, does not necessarily mean that the trophic condition of the lake can be improved by controlling nitrogen inputs. In many cases, the apparent condition of nitrogen-limitation results from excessive phosphorus input from point sources and is often accompanied by a corresponding increase in primary production. In such cases, the reversal of the enriched condition depends upon phosphorus control, not nitrogen control.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Virginia National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi). Sampling was begun in July, 1973, and was completed in May, 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Virginia District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in $kg/km^2/year$, at stations B-1, C-1, and D-1 and multiplying the means by the ZZ area in km^2.

The operator of the Henrico County-Sandston wastewater treatment plant provided monthly effluent samples and corresponding flow data. The operators of the New Kent Elementary School and Henrico County-Highland Springs plants participated in the Survey but did not submit flow data. Nutrient loads for these plants were estimated at 1.134

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* See Working Paper No. 175.

kg P and 3.401 kg N/capita/year. The load calculated for the Henrico County-Highland Springs plant (abandoned in April, 1974) is based on ten months of discharge.

The operators of the Leadbetter Industrial Park, Henrico County-Glenwood Farms, and Hanover County-Oak Hill Estates plants also provided samples, but these plants are far upstream and are not considered to be significant point sources; however, the data obtained are included in Appendix E for the record.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
New Kent Elem.* School	155	sand filter	58.7**	Allens Run
Henrico County-Sandston†	4,900	tr. filter	1,644.5	Broad Water Creek
Highland† Springs	3,360	tr. filter	1,271.8**	Unnamed trib. to Chickahominy R.

2. Known industrial - None

* Brown, 1973.
** Flow estimated at 0.3785 m^3/capita/day.
† Gregory, 1973.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Chickahominy River (A-2 & -3)	10,470	53.8
Tonyham Swamp	105	0.5
Collins Run	450	2.3
Big Swamp	570	2.9
b. Minor tributaries & immediate drainage (non-point load) -	925	4.8
c. Known municipal STP's -		
Henrico County -		
Sandston	3,475	17.9
Highland Springs	3,175	16.3
New Kent Elem. School	175	0.9
d. Septic tanks* -	20	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	105	0.5
Total	19,470	100.0

2. Outputs -

Lake outlet - Chickahominy River (including aqueduct)	15,325

3. Net annual P accumulation - 4,145 kg.

* Estimate based on 73 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Chickahominy River (A-2 & -3)	186,775	81.3
Tonyham Swamp	1,195	0.5
Collins Run	4,665	2.0
Big Swamp	3,930	1.7
b. Minor tributaries & immediate drainage (non-point load) -	8,380	3.7
c. Known municipal STP's -		
Henrico County -		
Sandston	7,335	3.2
Highland Springs	9,520	4.2
New Kent Elem. School	525	0.2
d. Septic tanks* -	780	0.3
e. Known industrial - None	-	-
f. Direct precipitation** -	6,555	2.9
Total	229,660	100.0

2. Outputs -

Lake outlet - Chickahominy River (including aqueduct)	227,575

3. Net annual N accumulation - 2,085 kg.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Chickahominy River	15	268
Tonyham Swamp	21	234
Collins Run	25	262
Big Swamp	39	267

* Estimate based on 73 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	3.21	0.68	37.8	0.34

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Chickahominy Lake:

"Dangerous" (eutrophic loading)	1.22
"Permissible" (oligotrophic loading)	0.61

V. LITERATURE REVIEWED

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
5103	CLAYTOR LAKE	0.031	0.450	439.500	5.642	14.900	0.008
5105	JOHN W. FLANNAGAN DAM	0.011	0.320	415.700	5.955	14.800	0.004
5106	JOHN H. KERR RESERVOIR	0.044	0.290	458.937	8.833	15.000	0.009
5108	OCCOQUAN RESERVOIR	0.098	0.525	459.750	12.417	15.000	0.037
5110	SMITH MOUNTAIN LAKE	0.016	0.410	419.667	11.593	15.000	0.005
5111	LAKE CHESDIN	0.044	0.240	465.778	12.556	14.800	0.008
5112	CHICKAHOMINY LAKE	0.066	0.125	455.333	13.600	9.400	0.017
5113	RIVANNA (SOUTH FORK) RES	0.079	0.475	460.222	6.667	13.000	0.022

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
5103	CLAYTOR LAKE	71 (5)	29 (2)	71 (5)	100 (7)	43 (3)	64 (4)	378
5105	JOHN W. FLANNAGAN DAM	100 (7)	57 (4)	100 (7)	86 (6)	64 (4)	100 (7)	507
5106	JOHN H. KERR RESERVOIR	43 (3)	71 (5)	43 (3)	57 (4)	14 (0)	43 (3)	271
5108	OCCOQUAN RESERVOIR	0 (0)	0 (0)	29 (2)	29 (2)	14 (0)	0 (0)	72
5110	SMITH MOUNTAIN LAKE	86 (6)	43 (3)	86 (6)	43 (3)	14 (0)	86 (6)	358
5111	LAKE CHESDIN	57 (4)	86 (6)	0 (0)	14 (1)	64 (4)	64 (4)	285
5112	CHICKAHOMINY LAKE	29 (2)	100 (7)	57 (4)	0 (0)	100 (7)	29 (2)	315
5113	RIVANNA (SOUTH FORK) RES	14 (1)	14 (1)	14 (1)	71 (5)	86 (6)	14 (1)	213

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	5105	JOHN W. FLANNAGAN DAM	507
2	5103	CLAYTOR LAKE	378
3	5110	SMITH MOUNTAIN LAKE	358
4	5112	CHICKAHOMINY LAKE	315
5	5111	LAKE CHESDIN	285
6	5106	JOHN H. KERR RESERVOIR	271
7	5113	RIVANNA (SOUTH FORK) RES	213
8	5108	OCCOQUAN RESERVOIR	72

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR VIRGINIA 02/05/76

LAKE CODE 5112 CHICKAHOMINY LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 774.4

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
5112A1	774.4	10.48	12.46	14.72	12.46	7.93	4.81	4.53	5.38	3.40	3.96	6.23	8.50	7.88
5112A2	153.8	2.10	2.52	2.83	2.55	1.61	1.16	0.93	1.08	0.74	0.79	1.36	1.76	1.61
5112A3	543.9	7.36	8.78	10.19	8.50	5.66	3.40	3.11	3.68	2.49	2.83	4.25	5.95	5.50
5112B1	5.1	0.06	0.10	0.12	0.08	0.05	0.05	0.03	0.03	0.02	0.03	0.04	0.05	0.06
5112C1	17.8	0.23	0.31	0.40	0.28	0.19	0.16	0.11	0.13	0.08	0.09	0.17	0.20	0.20
5112D1	14.7	0.19	0.27	0.31	0.27	0.16	0.14	0.09	0.11	0.07	0.08	0.14	0.17	0.17
5112ZZ	43.3	0.59	0.74	0.88	0.74	0.45	0.37	0.25	0.31	0.20	0.23	0.40	0.48	0.47

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 774.4
SUM OF SUB-DRAINAGE AREAS = 778.5

TOTAL FLOW IN = 96.28
TOTAL FLOW OUT = 94.86

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
5112A1	7	73	5.52	14	3.51				
	8	73	4.81	12	1.61				
	9	73	2.27	8	1.67				
	10	73	3.34	13	2.32				
	11	73	3.14	10	3.91	11	3.91		
	12	73	12.03	8	4.11				
	1	74	14.38	12	14.38				
	2	74	9.34	9	11.55				
	3	74	11.61	23	16.71	24	14.72		
	4	74	13.59	20	8.50				
	5	74	8.50	5	8.50				
5112A2	7	73	0.85	14	0.48				
	8	73	0.76	12	0.23				
	9	73	0.37	8	0.25				
	10	73	0.65	13	0.45				
	11	73	0.62	10	0.76	11	0.76		
	12	73	2.27	8	0.71				
	1	74	2.61	12	2.61				
	2	74	2.04	9	2.35				
	3	74	2.32	23	3.40	24	2.97		
	4	74	2.69	20	1.76				
	5	74	1.78	5	1.78				

TRIBUTARY FLOW INFORMATION FOR VIRGINIA 02/05/76

LAKE CODE 5112 CHICKAHOMINY LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
5112A3	7	73	3.54	14	2.27				
	8	73	3.26	12	0.11				
	9	73	1.53	8	1.10				
	10	73	2.35	13	1.64				
	11	73	1.73	10	2.35	11	2.35		
	12	73	8.78	8	1.25				
	1	74	10.19	12	14.16				
	2	74	10.05	9	8.92				
	3	74	8.24	23	11.84	24	10.48		
	4	74	8.35	20	5.66				
	5	74	3.54	5	3.34				
5112B1	7	73	0.01	14	0.06				
	8	73	0.02	12	0.00				
	9	73	0.01	8	0.01				
	10	73	0.02	13	0.02				
	11	73	0.02	10	0.03	11	0.03		
	12	73	0.06	8	0.02				
	1	74	0.07	12	0.07				
	2	74	0.07	9	0.08				
	3	74	0.08	23	0.12	24	0.10		
	4	74	0.09	20	0.07				
	5	74	0.07	5	0.07				
5112C1	7	73	0.06	14	0.03				
	8	73	0.06	12	0.02				
	9	73	0.03	8	0.02				
	10	73	0.07	13	0.05				
	11	73	0.07	10	0.09	11	0.09		
	12	73	0.22	8	0.07				
	1	74	0.26	12	0.26				
	2	74	0.25	9	0.28				
	3	74	0.28	23	0.40	24	0.34		
	4	74	0.31	20	0.21				
	5	74	0.22	5	0.22				
5112D1	7	73	0.03	14	0.03				
	8	73	0.06	12	0.01				
	9	73	0.03	8	0.02				
	10	73	0.06	13	0.04				
	11	73	0.06	10	0.07	11	0.07		
	12	73	0.18	8	0.06				
	1	74	0.21	12	0.21				
	2	74	0.20	9	0.23				
	3	74	0.23	23	0.34	24	0.28		
	4	74	0.25	20	0.17				
	5	74	0.18	5	0.18				

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/02/05

511201
37 24 37.0 076 56 33.0
CHICKAHOMINY LAKE
51 VIRGINIA

11EPALES
3

2111202
0010 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/09	09 30	0000	14.1		60	75	6.60	15	0.070	0.500	0.050	0.019
	09 30	0006	14.1	8.5		70	6.80	15	0.080	0.500	0.050	0.022
73/09/26	15 50	0000	23.5	5.6	36	76	6.50	21	0.050	1.000	0.030	0.010

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/09	09 30	0000	0.063	4.9
	09 30	0006	0.062	
73/09/26	15 50	0000	0.069	18.4

24

STORET RETRIEVAL DATE 76/02/05

511202
37 22 36.0 076 54 05.0
CHICKAHOMINY LAKE
51 VIRGINIA

11EPALES
3

2111202
0007 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/09	10 50	0000	14.5			70	6.80	15	0.080	0.700	0.070	0.018
	10 50	0005	14.5	8.4		70	6.80	16	0.070	0.600	0.060	0.017
73/09/26	15 35	0000	24.0	6.8	38	495	6.60	30	0.070	0.900	0.030	0.006
	15 35	0005	24.0			497						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/09	10 50	0000	0.069	11.0
	10 50	0005	0.092	
73/09/26	15 35	0000	0.054	20.1

25A

APPENDIX E

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 76/05/20

5112A1
37 24 25.0 076 56 18.0 4
CHICKAHOMINY RIVER
51 7.5 WALKERS
0/CHICKAHOMINY LAKE 021691
AT WALKERS DAM S OF WALKERS
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/07/14	16 10		0.044	1.300	0.037	0.023	0.065
73/08/12	10 00		0.010K	0.780	0.029	0.010	0.060
73/09/08	11 50		0.010K	1.890	0.014	0.023	0.175
73/10/13	10 50		0.015	0.700	0.036	0.015	0.060
73/11/10	10 45		0.010K	0.650	0.027	0.010	0.055
73/12/08	10 55		0.008	0.500	0.012	0.012	0.055
74/01/12	10 30		0.020	0.600	0.032	0.020	0.050
74/02/09	10 30		0.028	0.600	0.030	0.020	0.055
74/03/23	10 30		0.200	1.300	0.035	0.030	0.030
74/04/20	11 00		0.012	0.600	0.050	0.025	0.025
74/05/05	11 40		0.008	0.600	0.085	0.025	0.060

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/20

5112A2
37 25 44.0 077 02 18.0 4
CHICKAHOMINY RIVER S
51127 7.5 PROVIDENCE F
I/CHICKAHOMINY LAKE 021691
RT 115 BRDG 1.25 MI N OF SANDYBOTTOM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/07/14	16 55		0.140	0.600	0.100	0.056	0.100
73/08/12	10 35		0.092	0.800	0.078	0.078	0.120
73/09/08	10 50		0.010K	0.600	0.065	0.009	0.080
73/10/13	11 45		0.046	0.650	0.048	0.050	0.090
73/11/10	11 17		0.010K	0.550	0.024	0.040	0.070
73/12/08	11 45		0.010K	0.400	0.016	0.032	0.115
74/01/12	11 45		5.100	0.400	0.016	0.020	0.040
74/02/09	11 05		0.112	0.600	0.025	0.020	0.030
74/03/24	11 40		0.252	0.800	0.035	0.030	0.065
74/04/20	12 00		0.016	0.500	0.040	0.046	0.065
74/05/05	12 05		0.084	0.600	0.045	0.045	0.080

K VALUE KNOWN TO BE
LESS THAN INDICATED

28
A

STORET RETRIEVAL DATE 76/05/20

5112A3
37 26 00.0 077 02 15.0 4
CHICKAHOMINY RIVER N
51127 7.5 PROVIDENCE F
T/CHICKAHOMINY LAKE 021691
RT 115 BRDG 1.5 MI N OF SANDYBOTTOM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/07/14	16 25		0.138	0.840	0.066	0.052	0.100
73/08/12	10 30		0.150	0.770	0.040	0.081	0.115
73/09/08	11 20		0.138	3.150	0.046	0.056	0.100
73/10/13	11 10		0.086	0.600	0.042	0.054	0.110
73/11/10	11 10		0.010K	1.000	0.054	0.039	0.070
73/12/08	11 30		0.010K	0.400	0.012	0.036	0.095
74/01/12	11 00		0.012	0.600	0.020	0.020	0.045
74/02/09	10 55		0.112	0.300	0.020	0.020	0.035
74/03/24	11 30		0.108	0.700	0.025	0.030	0.065
74/04/20	11 45		0.024	0.500	0.040	0.045	0.065
74/05/05	12 00		0.100	0.700	0.060	0.045	0.070

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/20

511281
37 24 25.0 076 59 58.0 4
TONYHAM SWAMP
51 7.5 WALKERS
T/CHICKAHOMINY LAKE 021691
SEC RD BRDG 3 MI E OF SANDYBOTTOM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/07/14	17 25		0.084	0.460	0.024	0.046	0.075
73/08/12	11 00		0.048	0.165	0.018	0.056	0.110
73/09/08	11 45		0.024	3.150	0.023	0.058	0.095
73/10/13	11 30		0.014	0.250	0.016	0.047	0.070
73/11/10	11 32		0.010K	0.250	0.013	0.039	0.070
73/12/08	14 29		0.010K	0.500	0.012	0.024	0.050
74/01/12	11 30		0.012	0.300	0.008	0.024	0.050
74/02/09	11 15		0.028	0.300	0.020	0.015	0.035
74/03/24	13 05		0.060	1.000	0.030	0.020	0.055
74/04/20	12 35		0.016	0.250	0.015	0.025	0.025
74/05/05	12 20		0.024	0.300	0.025	0.030	0.065

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/20

5112C1
37 24 40.0 077 02 30.0 4
COLLINS RUN
51 7.5 PROVIDENCE F
T/CHICKAHOMINY LAKE 021691
RT 614 BRDG .25 MI E OF SANDYBOTTOM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/07/14	17 05		0.130	0.830	0.044	0.048	0.085
73/08/12	10 45		0.092	1.260	0.053	0.058	0.090
73/09/08	11 35		0.084	0.220	0.044	0.058	0.100
73/10/13	11 20		0.065	0.650	0.200	0.044	0.085
73/11/11	11 25		0.010K	0.200	0.026	0.040	0.077
73/12/08	13 30		0.028	0.100	0.008	0.028	0.085
74/01/12	11 20		0.040	0.300	0.020	0.032	0.070
74/02/09	11 05		0.116	1.300	0.130	0.020	0.080
74/03/24	13 45		0.104	1.100	0.045	0.025	0.050
74/04/20	12 15		0.040	0.200	0.010	0.035	0.040
74/05/05	12 40		0.060	1.100	0.037	0.040	

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/20

511201
37 25 44.0 076 59 16.0 4
BIG SWAMP
51 7.5 WALKERS
T/CHICKAHOMINY LAKE 021691
US 60 E BOUND LANE BRDG W OF WINDSOR SHA
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/07/14	16 40		0.110	0.960	0.063	0.095	0.160
73/08/12	10 10		0.080	0.520	0.037	0.091	0.210
73/09/08	11 05		0.061	1.100	0.045	0.093	0.155
73/10/13	10 55		0.046	0.450	0.052	0.063	0.125
73/11/10	11 00		0.010K	0.400	0.030	0.054	0.090
73/12/08	11 00		0.028	1.100	0.040	0.064	0.130
74/01/12	10 40		0.036	0.400	0.036	0.044	0.085
74/02/09	10 45		0.060	0.500	0.075	0.030	0.050
74/03/24	14 20		0.064	1.000	0.067	0.040	0.085
74/04/20	11 15		0.028	0.600	0.035	0.055	0.055
74/05/05	11 45		0.044	0.400	0.060	0.070	0.115

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/20

5112FA SF5112FA P000155
37 31 45.0 077 05 57.0 4
NEW KENT CO WATKINS ELEM SCH
51 7.5 TUNSTALL
T/LAKE CHICKAHOMINY 021592
ALLENS RUN/KENT LAKE/TOE INK SWAMP
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/05/07			48.000	3.800	0.670	11.500	14.000		
74/06/04	15 00		57.000	4.300	0.460	10.500	11.500		
74/07/09	09 00		39.000	5.700	0.160	15.000	15.700		
74/08/05	10 00		26.000	2.000	0.061	10.500	11.100		
74/09/05	14 00		16.800	1.600	0.120	6.450	6.900		
74/10/04			44.000	5.800	0.058	2.600	3.750		
74/11/04	15 00		59.400	4.500	0.100	11.500	11.500		
74/12/02			46.100	3.700	1.400	6.400	6.900		
75/01/09			20.000	24.000	8.800	7.250	9.500		
75/02/01			56.850	15.000	8.910	7.175	7.300		
75/03/06	14 30		49.700	2.300	2.080	12.300	10.500L		

L ACTUAL VALUE IS KNOWN TO BE
GREATER THAN VALUE GIVEN

STORET RETRIEVAL DATE 76/05/20

5112GA P05112GA P000115
34 45 10.0 077 29 30.0 4
OAK HILL ESTATES ASHLAND
51 7.5 ASHLAND
T/LAKE CHICKAHOMINY
STONY RUN
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/09/28	11 00		0.130	7.100	0.460	6.500	7.500		

STORET RETRIEVAL DATE 76/05/20

5112VA PD5112VA
37 45 25.0 077 29 15.0 4
LEDBETTER INDUST. PARK, ASHLAND
51 7.5 ASHLAND
T/CHICKAHOMINY LAKE 021591
STONY RUN
11EPALES 2141204
0000 FEET DEPTH CLASS 00

35 A

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/07	12 00		0.240	4.700	1.720	0.165	0.880	0.085	0.085

STORET RETRIEVAL DATE 76/05/20

5112XA TF5112XA P004900
37 31 20.0 077 16 00.0 4
HENRICO CO S/D 2 RICHMOND
51 7.5 SEVEN PINES
T/LAKE CHICKAHOMINY 021692
UNNAMED TRIB/BOAR SWAMP/CHICKAHOMINY RIV
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/24	11	00							
CP(T)-			7.560	3.300	1.040	3.200	4.100	0.430	0.420
74/01/24	15	00							
74/02/26	11	15							
CP(T)-			6.800	2.700	1.100	2.600	3.700	0.420	0.430
74/02/26	15	15							
74/04/03	10	00							
CP(T)-			6.000	2.000	0.220	2.800	4.600	0.450	0.440
74/04/03	15	30							
74/04/30	15	00	13.000	5.700	0.980	7.600	9.300	0.450	0.450
74/05/28	10	30							
CP(T)-			12.600	4.800	0.540	6.400	7.900	0.430	0.440
74/05/28	15	00							
74/07/02	10	00							
CP(T)-			10.900	2.900	0.120	7.700	8.800	0.400	0.410
74/07/02	15	00							
74/08/26			5.020	1.500	0.175	2.100	2.500		
74/10/25	09	00							
CP(T)-			10.400	2.600	0.260	7.100	7.100		0.600
74/10/25	13	30							
74/11/26	09	15							
CP(T)-									0.120
74/11/26	15	00							
74/12/13	08	30							
CP(T)-			11.200	3.100	0.140	5.600	6.550	0.120	0.120
74/12/13	12	00							
75/01/22	09	00							
CP(T)-			6.100	1.300	0.070	1.150	1.700	0.600	0.600
75/01/22	13	30							

STORET RETRIEVAL DATE 76/05/20

5112YA TF5112YA P002895
37 33 07.0 077 19 23.0 4
HENRICO CO SAN DIST 4 HIGHLAND
51 7.5 SEVEN PINES
T/CHICKAHOMINY LAKE 021692
UNNAMED STREAM/CHICKAHOMINY RIVER
11EPALES 2141204
0000 FEET DEPTH CLASS 00

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DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/24	11 00								
CP(T)-			1.240	13.500	6.900	6.160	7.000		
74/01/24	15 00								
74/02/26	11 00								
CP(T)-			0.920	15.000	6.300	5.800	7.600		
74/02/26	15 00								
74/04/03	10 15								
CP(T)-			0.600	20.000	3.600	5.550	10.000		
74/04/03	15 15								

STORET RETRIEVAL DATE 76/05/20

S112ZA ASS112ZA P000282
37 34 50.0 077 23 18.0 4
HENRICO CO GLENWOOD FARMS,RICHMO
51 7.5 RICHMOND
T/CHICKAHOMINY LAKE 021691
UNNAMED STREAM/CHICKAHOMINY RIVER
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/24	11 00								
CP(T)-			0.640	17.000	8.900	5.520	8.000		
74/01/24	15 00								
74/02/26	10 45								
CP(T)-			0.640	14.000	8.600	5.900	8.400		
74/02/26	14 45								

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